CRN5EXP - EXPERT SYSTEM FOR STATISTICAL QUALITY CONTROL

Mariana Hentea, Senior Consultant
Interactive Business Systems, Oak Brook, Illinois

ABSTRACT. The purpose of the Expert System CRN5EXP is to help the user to check the quality of the coils at two very important mills: Hot Rolling and Cold Rolling in a steel plant. The system interprets the statistical quality control charts, diagnoses and predicts the quality of the steel. Measurements of process control variables are recorded in database (ADABAS) and sample statistics such as the mean and the range are computed and plotted on a control chart. The chart is analyzed through patterns using CLIPS and forward chaining technique to reach a conclusion about the causes of defects and to take management measures for the improvement of the quality control techniques.

The Expert System combines the certainty factors associated with the process control variables to predict the quality of the steel. The paper presents the approach to extract data from database, the reason to combine certainty factors, the architecture and the use of the Expert System. However, the interpretation of control charts patterns requires the human expert's knowledge and lends to Expert Systems rules.

The conclusions reached with this system help the management and the quality engineers to eliminate the special causes of the process control variable variations and to correct about 85% of the problems from these mills.

EXPERT SYSTEM OVERVIEW

The purpose of the Expert System CRN5EXP is to help the user to track the quality of the coils at two very important mills: hot rolling (HSM) and cold rolling (CRN5). The user needs this system to find out why the coils at CRN5 had gauge variation and what is the predicted quality of the coils produced at HSM.

Hot Rolling is an upstream process and Cold Rolling is a downstream process. The quality of the coils is measured primarily by gauge, every coil produced at CRN5 should have the gauge ordered by customer. If a coil doesn't have the dimensions required by the customer then it is rejected. At CRN5, the gauge variation is a function of the mill set-up, such as: work rolls, diameters, tons of coils rolled between roll changes, frequency of roll changes, maintenance, hardness of work roll surface, roll forces, tension, speed, motor power. At HSM, the gauge variation is a function of the finishing and coiling temperatures.

The implemented software is a complex of NATURAL programs which search database files (ADABAS) for the coils which have gauge variations. The program contains routines which calculate the control charts using statistical method FORD. Control charts

give a good indication of whether any problems are likely to be correctable locally or will require a management action. The database files (ADABAS), on mainframe IBM, store process control variables specific to each process: hot rolling and cold rolling.

The coils which are not in statistical control for the gauge at cold rolling and hot rolling are downloaded from database files to PC files (ASCII) which are the input data for the Expert System. The present Expert System contains rules to check the variables specific to each mill. The user may select the coils produced during a period of time by entering the starting and ending dates.

SYSTEM FUNCTIONS:

CHECK THE COILS AT CRN5

CHECK THE COILS AT HSM

The user from cold mill is interested to find the causes of the gauge variations for the coils. The knowledge about mill set-up and actual process control variables help the management to eliminate special causes of gauge variations and to correct about 85% of process control problems.

The Expert System reads the data from the input file, checks the values of the varibles and provides a detailed report of the running mill. At CRN5, the process control variables, such as: tons of coils rolled between roll changes, work roll numbers, diameters, surface, frequency of roll changes, roll forces, tension, speed, and motor power are compared with the computer predicted values. The Expert System analyzes the data and issues conclusions regarding these variables. The present System is able to reach more than twenty conclusions. At HSM, the software checks the coiling and finishing temperature values.

The Expert System implements two functions: checks the coils produced at CRN5 and the coils at HSM. If the user selects the option to check the coils produced at CRN5, the Expert System analyzes the process control variables recorded at CRN5. If the actual variables are within the standards allowed for this mill, then the Expert System checks the variables recorded at HSM. If the actual variables, finishing and coiling temperatures, are within the standards allowed for the HSM, then the Expert System advices the user to search process control variables from another mill (pickle), which may had caused the gauge variations (not implemented yet). If the actual variables from CRN5 are not within the standards, then the Expert System issues different conclusions and advices managerial actions. If the actual variables from CRN5 are within the standards, then the Expert System checks the actual variables recorded at HSM. If the actual temperatures are not within the standards, then the Expert System indicates the quality of the produced coil at HSM. At user request, the Expert System provides an explanation facility which gives a detailed report about the values of actual temperatures and the way they influenced the quality of the produced coil. The finishing and coiling temperatures influence the quality of

the coil which is stated as normal, soft or hard. If the user selects the option to check the coils produced at HSM, then the Expert System checks the variables recorded at HSM and predicts the quality of the coil. The Expert System helps the user from CRN5 to determine the quality of the incomming coils and based on that to compute the values for the model which are the standards for CRN5. The Expert System is used in both mills to improve the quality of the produced coils.

EXPERT SYSTEM KNOWLEDGE

The present system implements the knowledge in rules based on the information acquired from the experts (metallurgist, chemist, quality and process control engineers). The metallurgist and quality engineers consider that the values of roll forces, tension, speed, and motor power are determined by the the coil hardness. If the roll forces are high, above the predicted values, then it is an indication that incomming coil is hard. If the roll forces are low, below the predicted values, then it is an indication that the incomming coil is soft.

The program checks first all the variables specific to CRN5. If all the variables are in statistical control, then the program checks the variables from the upstream process. The program implements rules to set-up the certainty factors for different temperature ranges, based on the specialist's experience. For example, if the finishing temperature is below or above AIMS temperature (standard value based on the grade of the steel) more than 30 degrees Fahrenheit, then the coil is not certainly normal: it is hard or soft with a certainty factor. The system displays to the user the term "probability". If the finishing temperature is above the AIMS, then the coil is considered soft. If the finishing temperature is below of the AIMS temperature, then the coil is considered hard.

If the coiling temperature is not within the upper and lower limits (standard values based on the grade of the steel) then the coil is not certainly normal. If the coiling temperature is above the upper limit than the coil is soft. If the coiling temperature is below the lower limit then the coil is considered hard. Even though the temperatures are within limits, the certainty factor that a coil is normal is reduced by the certainty factors of each temperature value. The certainty factors are combined using MYCIN formulas or expert's experience in some cases. It depends of the type of effect each temperature has on the quality of the hot rolled coil. The coiling is a variable measured before finishing temperatures, so its variation causes variations to the finishing temperatures.

Checking the coils at HSM may conclude that the temperatures were normal. The analysis of the coils with gauge variation prove that there are all kinds of causes for that: process control variables outside of the ranges allowed in the mill, maintenance problems, wrong computer model.

USE OF THE SYSTEM

The Expert System implements two functions displayed on the main menu. The user can select one option and the program loads the facts in memory. The input data is read from the ASCII files (the variables specific to CRN5 and HSM are stored in separate files). The user may check a coil produced at CRN5 or at HSM. The Expert System implements also an explanation facility, the user can check why the hardness of the coil is normal, hard, or soft. The user is informed about the values of certainty factors for the coiling and finishing temperature which influence the certainty factor for the hardness of the rolled coil at HSM. By knowing the hardness of the coil expressed in certainty factor, the process control engineers can take managerial actions to improve the mill set-up.

EXPERT SYSTEM ARCHITECTURE

The system contains eighty rules. The facts for option one are loaded from the file containing the process control variables specific to CRN5. The facts for option two are loaded from the file containing the process control variables specific to HSM.

The system reaches more than twenty conclusions regarding the quality of the coil and the mill set-up.

The explanation facility uses a text file to store all the knowledge which supports a conclusion for every option. The certainty factors were used to combine facts about coiling and finishing temperatures to predict the quality of the coil (normal, hard, or soft).

EXPERT SYSTEM FOR STATISTICAL QUALITY CONTROL

The present Expert System interprets the statistical quality control charts to monitor, diagnose, and predict the possible quality of the coil.

In many companies, it is a frustrating struggle to train and educate the personnel on the proper use of control charts. Therefore, it is reasonable to provide a uniform interpretation of the control charts and to establish a state of control during manufacturing process. The Expert System significantly improves the quality control techniques.

REFERENCES

Hayes-Roth, F., D. A. Waterman and D. B. Lenat (1983). Building Expert Systems. Addison-Wesley, Redding.

Giarratano, J. C. and G. Riley (1989). Expert Systems : principles and programming. PWS-Kent, Boston.